Appendix A - Information from the watercourse manager of Nové Mlýny reservoir to possibility of operation of floating PV on the reservoir

As part of the analysis for the bachelor's thesis "Analysis of floating photovoltaic usage in the Czech Republic", the watercourse manager of Nové Mlýny reservoir was questioned about theoretical possibility floating PV plant operation on the reservoir. Part of these questions were focused on specific data related to the reservoir. The answers were translated from the Czech language and editorially modified. The information was provided by Jindřich Grufík who also reflected information from his coworkers from the state company Povodí Moravy s.p.

Technical questions:

1. Q: The reservoir water-level variation (minimum and maximum) in the lower reservoir of Nové Mlýny?
   A: The variation is from 167.20 m to 171.60 m above sea level.
2. Q: The highs of waves, in case that waves are measured?
   A: The height of the waves is not measured; the Brno University of Technology is currently preparing the equipment for its measurement. According to experience, the height of the waves can be around 1 m on the windward side of the reservoir, where the floating PV plant position was selected.
3. Q: What is the maximal recorded temperature of the reservoir water and maximal thickness of ice on the surface of the reservoir?
   A: Based on last 5 years measurement, the maximal recorded temperature was 27.2 °C and 30 cm for maximal thickness of ice cover.
4. Q: Possibility to anchoring the floating PV plant to the reservoir bed or to a levee of the reservoir?
   A: It would be possible to anchor the plant to the bottom of the reservoir at whatever depth. There is no possibility anchoring into a levee.
5. Q: The depth of the reservoir at selected place (GPS: 48.8575314N, 16.7149908E)?
   A: Precise depth is unknown, because before construction the precise surveying of the reservoir bed was not made. But it can be around 3-6 m.

Question to floating PV plant:

Q: What is a view on the possibility of placing a floating photovoltaic power plant in the Nové Mlýny reservoir and the question of the co-operation of floating PV and hydroelectric power plants.

A:

- We see the placement of floating facilities, including the FPV plant, on these reservoirs is risky. The reservoirs are quite intensively used, and the level fluctuations on the reservoirs are high, ranging from a few meters to more than 10 m (in case of Nové Mlýny reservoir, see technical question 1) when considering the use of retention. The issue of ice phenomena and waves must also be considered.
- The project would also have to be assessed in terms of the impact of the PV plant on a body of backwater. In the case of water reservoirs, the collision of the operation of equipment, lines, accesses, etc., with the mode and conditions of water resource protection zones would have to be addressed. As with reservoirs, this is also applied to the Nove Mlýny reservoir, where usage of a levee or the dams (including access to them) is very restricted - except for the movement of pedestrians and cyclists. There is also limitation of access given by drain behind a levee.
- In general, we think that the placement of floating PV facilities on flowing valley reservoirs is not appropriate. In our view, the more suitable water surfaces for these facilities can be the surface of flooded quarries and mining pits, or gravel pits, where there are no significant variations in water levels and no clashes with other operational purposes. There is also a minimal risk to the safety of the waterworks and its operation.
- HSE (Health and Safety Executive), fire protection, protection of water from pollution during installation, operation, and accidents are entirely separate issues.

The information is based on email communication from 20th May, 2021 with Jindřich Grufík from state company Povodí Moravy s.p.

Version 7.2.1

PVsyst - Simulation report

Grid-Connected System

Project: PV Power project NOVE MLYNY

Variant: First simulation: simple system without perturbations

No 3D scene defined, no shadings

System power: 2534 kWp

Milovice - Czech Republic

Author

PVsyst V7.2.1
VC8, Simulation date:
28/05/21 08:32
with v7.2.1

Project summary

Geographical Site
Milovice
Czech Republic

Situation

Latitude	48.86 °N
Longitude	16.70 °E
Altitude	159 m
Time zone	UTC+1

Project settings
Albedo 0.20

Meteo data
Milovice
PVGIS api TMY

System summary

Grid-Connected System

No 3D scene defined, no shadings

PV Field Orientation
Fixed plane
Tilt/Azimuth 10 / -180 °

Near Shadings
No Shadings

User's needs
Unlimited load (grid)

System information

PV Array

Nb. of modules	6336 units
Pnom total	2534 kWp

Inverters

Nb. of units	22 units
Pnom total	2420 kWac
Pnom ratio	1.047

Results summary

Produced Energy	2315 MWh/year	Specific production	913 kWh/kWp/year	Perf. Ratio PR	84.08 %

Table of contents

General parameters

Grid-Connected System — **No 3D scene defined, no shadings**

PV Field Orientation

Orientation		Sheds configuration	Models used	
Fixed plane		No 3D scene defined	Transposition	Perez
Tilt/Azimuth	10 / -180 °		Diffuse	Imported
			Circumsolar	separate

Horizon	Near Shadings	User's needs
Free Horizon	No Shadings	Unlimited load (grid)

PV Array Characteristics

PV module

Manufacturer	Generic
Model	BSM400M-72
(Custom parameters definition)	
Unit Nom. Power	400 Wp
Number of PV modules	6336 units
Nominal (STC)	2534 kWp
Modules	396 Strings x 16 In series
At operating cond. (50°C)	
Pmpp	2337 kWp
U mpp	592 V
I mpp	3950 A

Inverter

Manufacturer	Generic
Model	STP 110-60
(Custom parameters definition)	
Unit Nom. Power	110 kWac
Number of inverters	22 units
Total power	2420 kWac
Operating voltage	500-800 V
Pnom ratio (DC:AC)	1.05

Total PV power

Nominal (STC)	2534 kWp
Total	6336 modules
Module area	12294 m²

Total inverter power

Total power	2420 kWac
Nb. of inverters	22 units
Pnom ratio	1.05

Array losses

Thermal Loss factor
Module temperature according to irradiance
Uc (const) 20.0 W/m²K
Uv (wind) 0.0 W/m²K/m/s

DC wiring losses
Global array res. 2.5 mΩ
Loss Fraction 1.5 % at STC

Module Quality Loss
Loss Fraction 3.0 %

Module mismatch losses
Loss Fraction 1.0 % at MPP

IAM loss factor
ASHRAE Param: IAM = 1 - bo(1/cosi -1)
bo Param. 0.05

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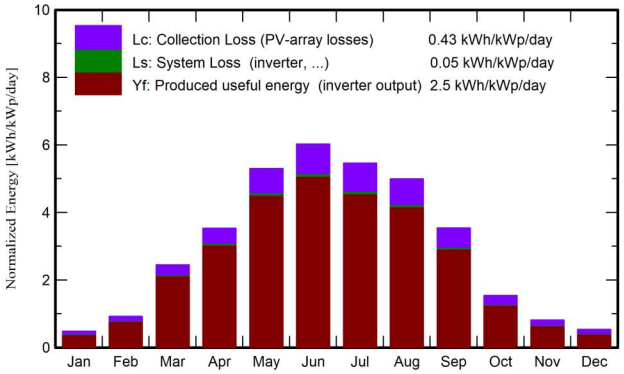
Main results

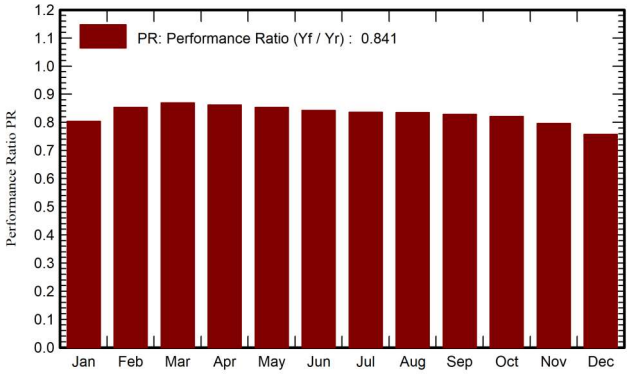
System Production

Produced Energy	2315 MWh/year	Specific production	913 kWh/kWp/year
		Performance Ratio PR	84.08 %

Normalized productions (per installed kWp)



Performance Ratio PR



Balances and main results

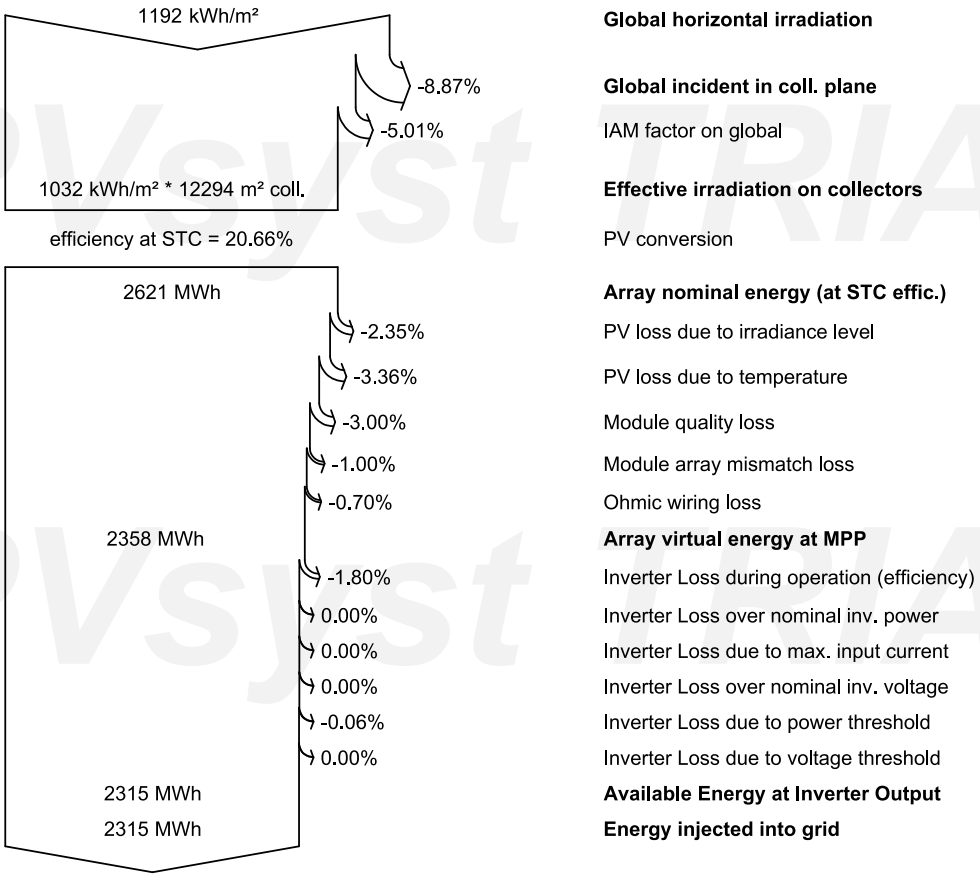
	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio
January	18.1	14.19	-0.69	14.9	13.7	32.2	30.4	0.804
February	29.1	23.61	0.93	25.6	23.8	57.1	55.5	0.854
March	87.3	48.95	5.11	75.9	71.0	170.3	167.2	0.869
April	115.1	62.63	10.47	106.0	100.8	235.8	231.6	0.862
May	173.3	73.59	15.35	164.2	157.9	360.5	354.8	0.853
June	187.7	84.64	19.23	180.8	174.5	392.5	386.2	0.843
July	177.0	82.14	21.73	169.1	163.1	364.5	358.5	0.836
August	168.7	66.11	21.00	154.9	148.1	333.1	327.8	0.835
September	123.1	44.99	17.73	106.1	99.3	226.6	222.6	0.828
October	57.2	33.61	12.01	47.6	43.6	101.5	99.1	0.821
November	32.2	19.64	5.88	24.4	21.6	50.8	49.2	0.796
December	23.1	14.92	2.13	16.5	14.3	33.6	31.7	0.758
Year	1191.9	569.02	10.96	1086.2	1031.8	2358.3	2314.7	0.841

Legends

GlobHor	Global horizontal irradiation
DiffHor	Horizontal diffuse irradiation
T_Amb	Ambient Temperature
GlobInc	Global incident in coll. plane
GlobEff	Effective Global, corr. for IAM and shadings
EArray	Effective energy at the output of the array
E_Grid	Energy injected into grid
PR	Performance Ratio

PVsyst V7.2.1
VC8, Simulation date:
28/05/21 08:32
with v7.2.1

Loss diagram



Global horizontal irradiation

Global incident in coll. plane

IAM factor on global

Effective irradiation on collectors

PV conversion

Array nominal energy (at STC effic.)

PV loss due to irradiance level

PV loss due to temperature

Module quality loss

Module array mismatch loss

Ohmic wiring loss

Array virtual energy at MPP

Inverter Loss during operation (efficiency)

Inverter Loss over nominal inv. power

Inverter Loss due to max. input current

Inverter Loss over nominal inv. voltage

Inverter Loss due to power threshold

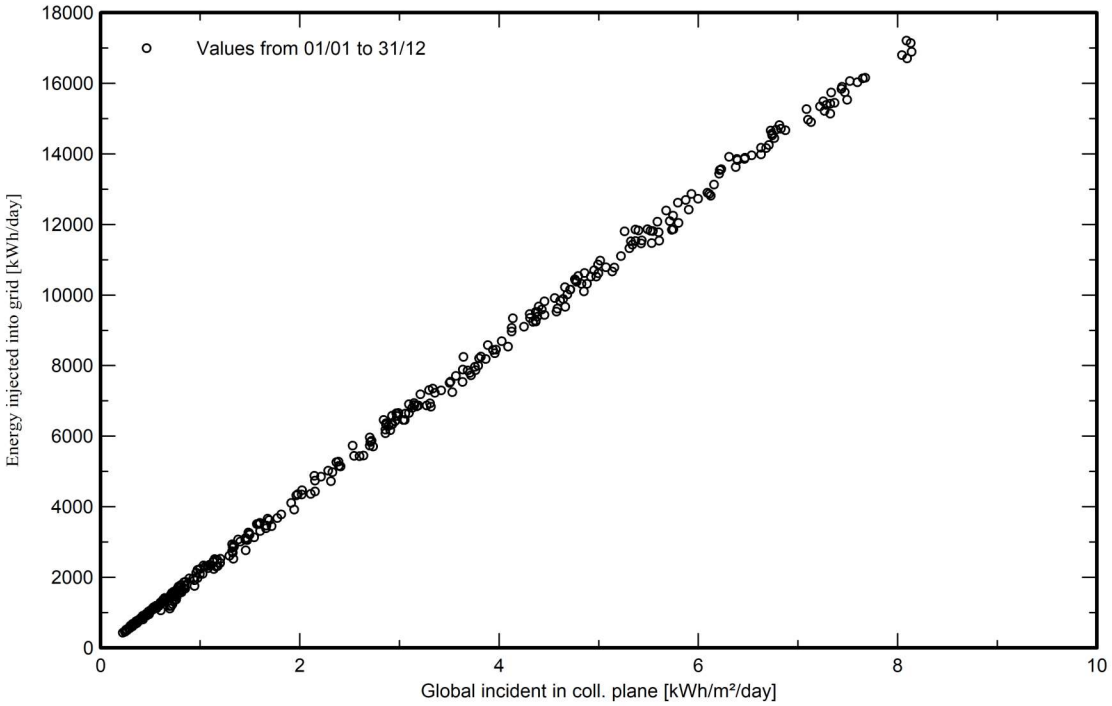
Inverter Loss due to voltage threshold

Available Energy at Inverter Output

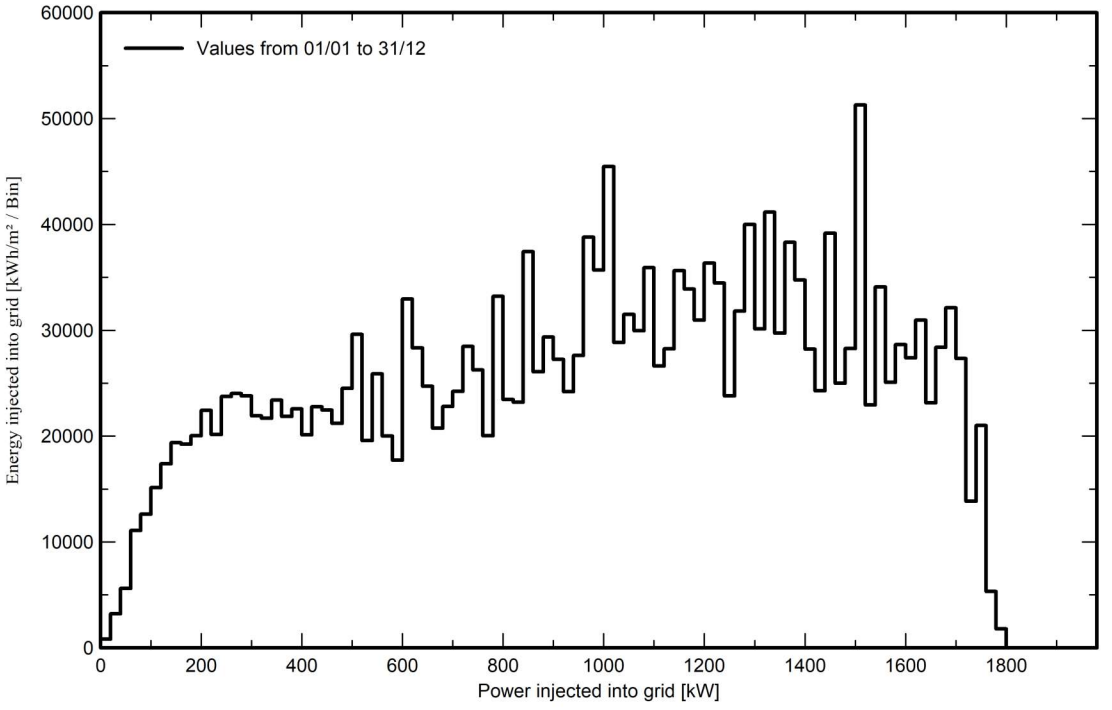
Energy injected into grid

Special graphs

Daily Input/Output diagram



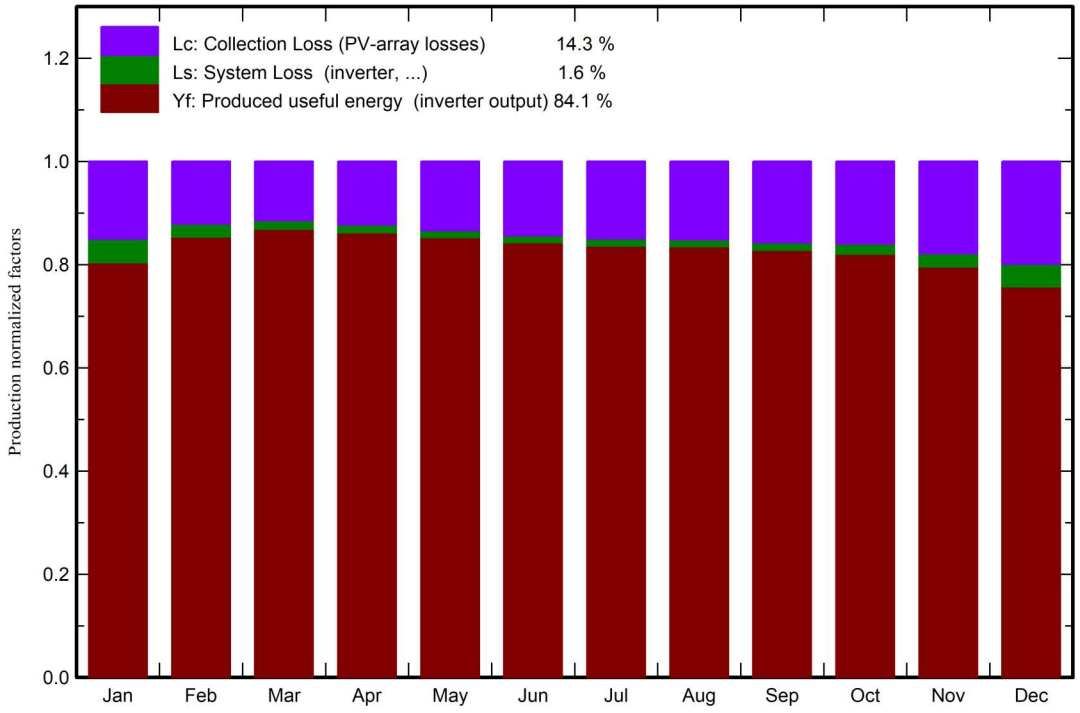
Distribution de la puissance de sortie système



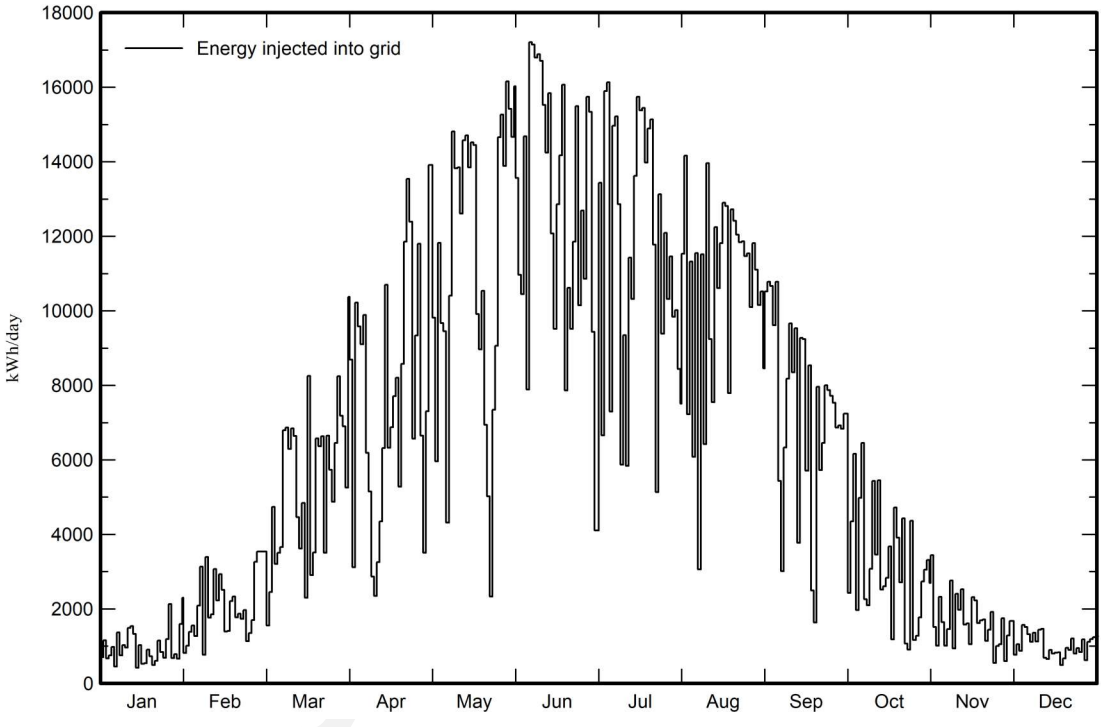
PVsyst V7.2.1
VC8, Simulation date:
28/05/21 08:32
with v7.2.1

Predef. graphs

Normalized Production and Loss Factors

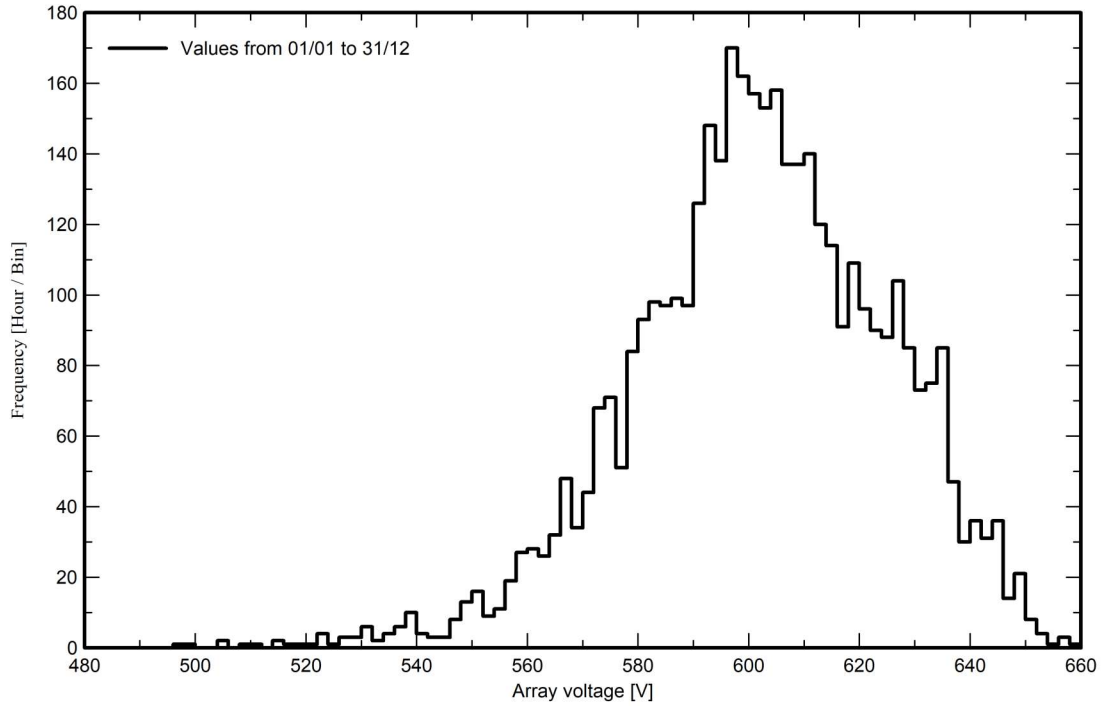


Energie journalière à la sortie du système



Predef. graphs

Distribution de la tension du champ



PV module - BSM400M-72

Manufacturer	Generic	**Commercial data**	
Model	BSM400M-72	Data source :	Manufacturer
Pnom STC power (manufacturer)	400 Wp	Technology	Si-mono
Module size (W x L)	0.992 x 1.956 m²	Rough module area (Amodule)	1.94 m²
Number of cells	1 x 72		

Specifications for the model (manufacturer or measurement data)

Reference temperature (TRef)	25 °C	Reference irradiance (GRef)	1000 W/m²
Open circuit voltage (Voc)	49.6 V	Short-circuit current (Isc)	10.59 A
Max. power point voltage (Vmpp)	40.8 V	Max. power point current (Impp)	9.82 A
=> maximum power (Pmpp)	400.5 W	Isc temperature coefficient (muIsc)	5.0 mA/°C

One-diode model parameters

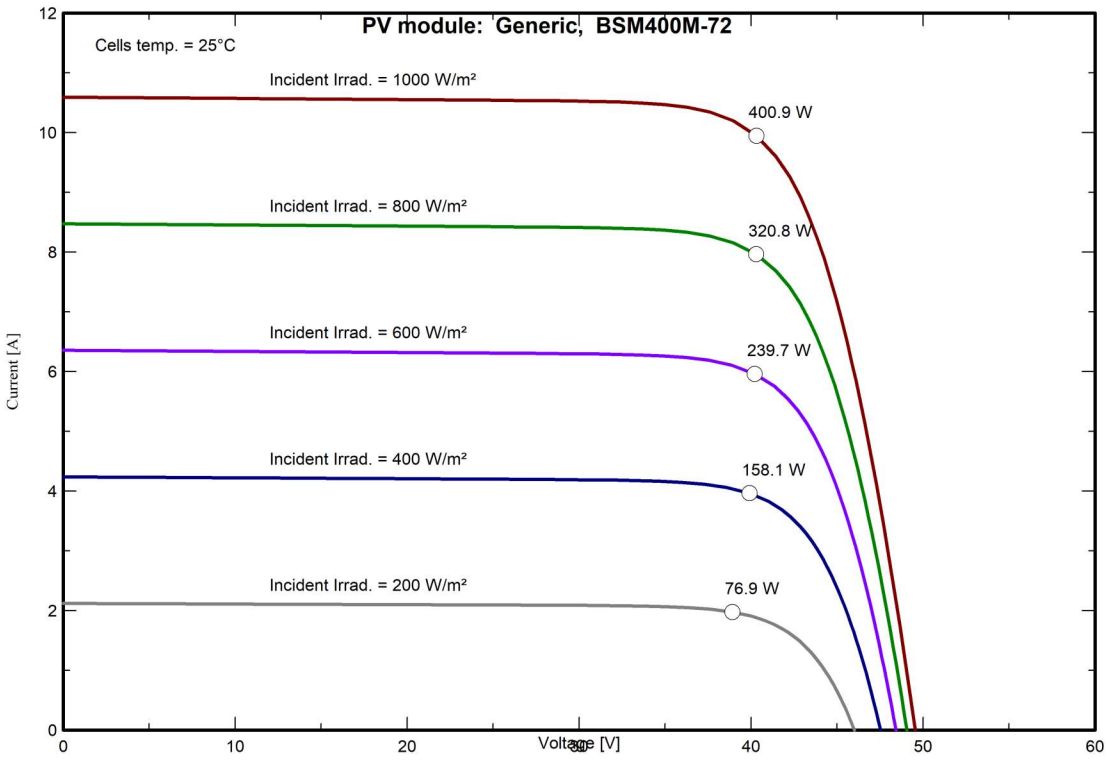
Shunt resistance (Rshunt)	500 Ω	Diode saturation current (IoRef)	1.49 nA
Serie resistance (Rserie)	0.29 Ω	Voc temp. coefficient (MuVoc)	-125 mV/°C
		Diode quality factor (Gamma)	1.18

Reverse Bias Parameters, for use in behaviour of PV arrays under partial shadings or mismatch

Reverse characteristics (dark) (BRev)	3.20 mA/V²	(quadratic factor (per cell))	
Number of by-pass diodes per module	1	Direct voltage of by-pass diodes	-0.7 V

Model results for standard conditions (STC: T=25 °C, G=1000 W/m², AM=1.5)

Max. power point voltage (Vmpp)	40.3 V	Max. power point current (Impp)	9.97 A
Maximum power (Pmpp)	400.9 Wp	Power temper. coefficient (muPmpp)	-0.32 %/°C
Efficiency(/ Module area) (Eff_mod)	20.7 %	Fill factor (FF)	0.764



Characteristics of a grid inverter

Manufacturer, model : **SMA, STP 110-60**

Data source : Manufacturer

500

Operating mode		**MPPT**			
Minimum MPP Voltage	**Vmin**	**N/A V**	Nominal PV Power	Pnom DC	110 kW
Maximum MPP Voltage	**Vmax**	**800 V**	Maximum PV Power	Pmax DC	165 kW
Absolute max. PV Voltage	Vmax array	1100 V	Maximum PV Current	Imax DC	N/A A
Min. Voltage for PNom	Vmin PNom	N/A V	Power Threshold	Pthresh.	1000 W
"String" inverter with input protections			Number of string inputs		24
Multi MPPT capability			Number of MPPT inputs		12
Behaviour at Vmin/Vmax		Limitation	Behaviour at Pnom		Limitation

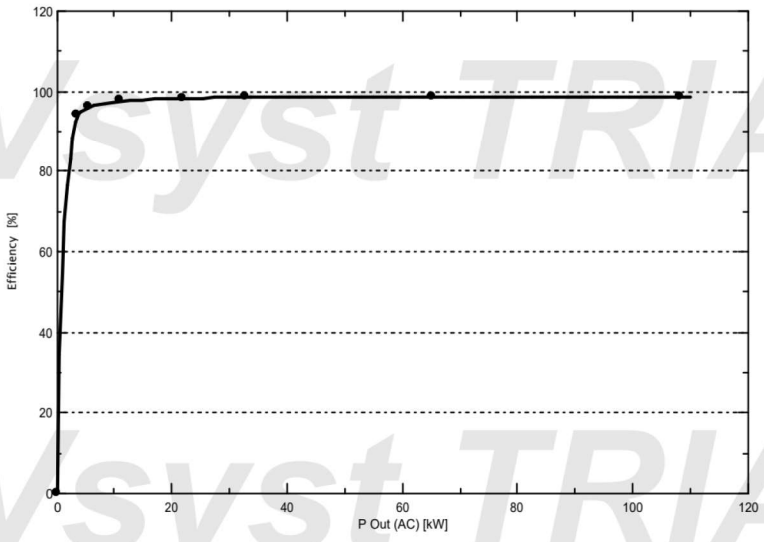
Output characteristics (AC grid side)

Grid Voltage	Unom	400 V	**Nominal AC Power**	**Pnom AC**	**110 kWac**
Grid frequency	Freq	50/60 Hz	Maximum AC Power	Pmax AC	110 kWac
	Triphased		Nominal AC current	Inom AC	130 A
Maximum efficiency	Max Eff.	98.6 %	Maximum AC current	Imax AC	159 A
European average efficiency	Euro Eff.	98.4 %			

Remarks and Technical features

Sizes: Width 1117 mm
Height 682 mm
Depth 363 mm
Weight 93.50 kg

Efficiency profile vs Output power



meteoblue
weather close to you

Climate Milovice

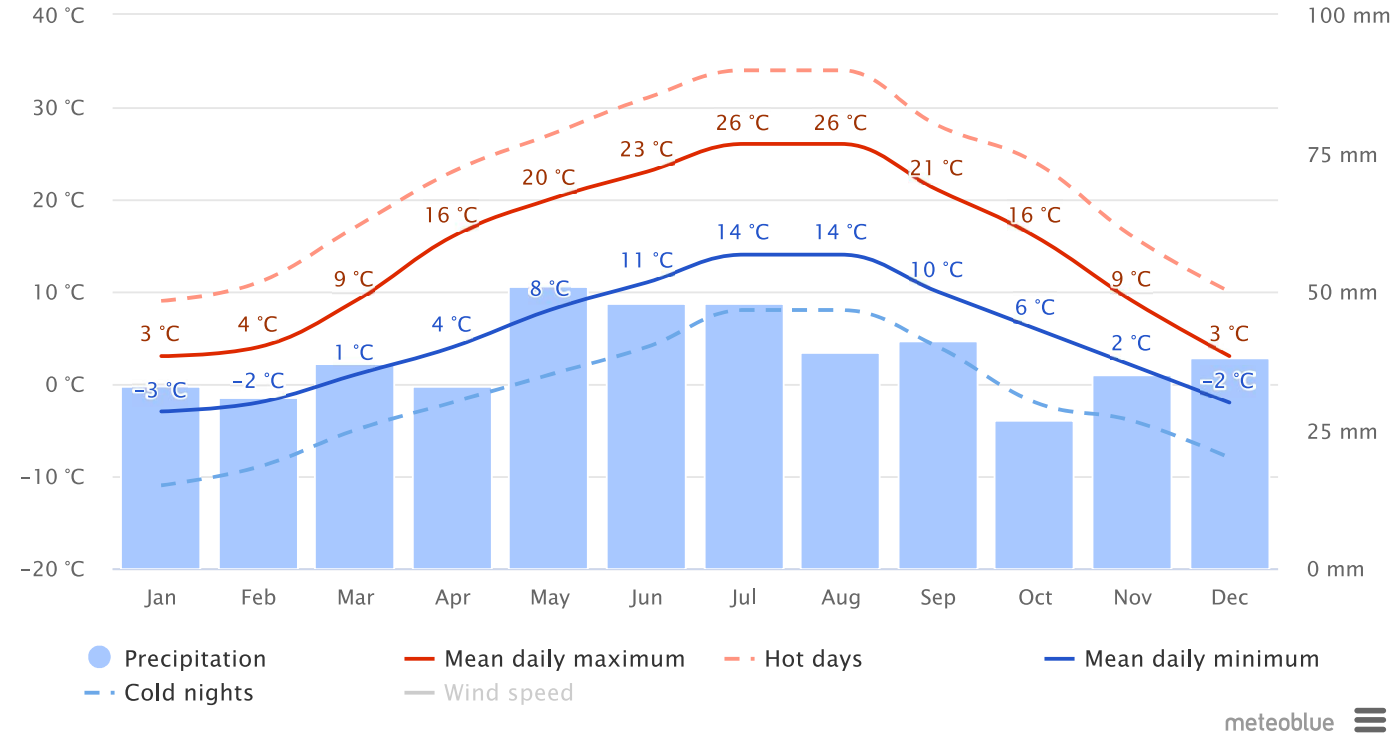
South Moravian, Czech Republic, 48.85°N 16.7°E, 178m asl

The meteoblue climate diagrams are based on 30 years of hourly weather model simulations and available for every place on Earth. They give good indications of typical climate patterns and expected conditions (temperature, precipitation, sunshine and wind). The simulated weather data have a spatial resolution of approximately 30 km and may not reproduce all local weather effects, such as thunderstorms, local winds, or tornadoes.

You can explore the climate for any location like the Amazon rainforest, West-Africa savannas, Sahara desert, Siberian Tundra or the Himalaya.

30 years of hourly historical weather data for Milovice can be purchased with history+. Download variables like temperature, wind, clouds and precipitation as CSV for any place on Earth. The last 2 weeks of past weather data for Milovice are available for free evaluation here.

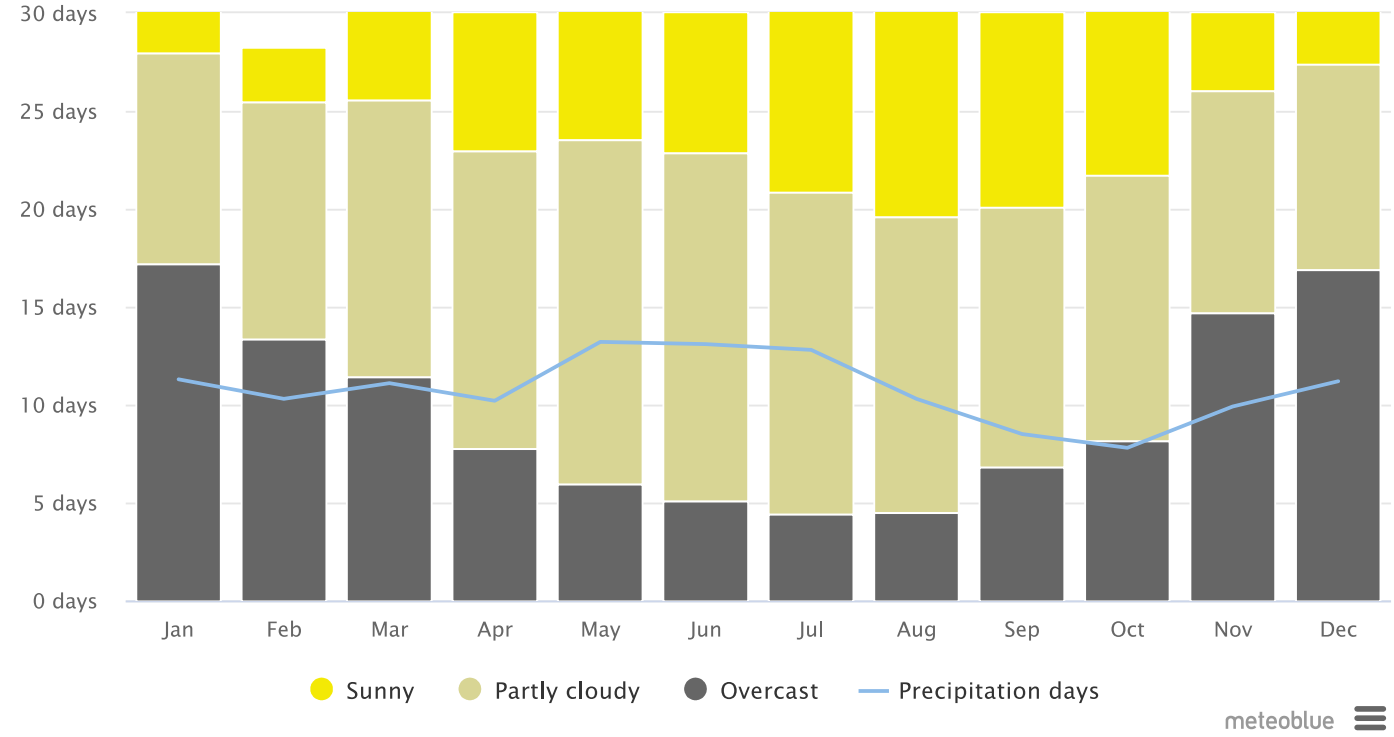
Average temperatures and precipitation



The "mean daily maximum" (solid red line) shows the maximum temperature of an average day for every month for Milovice. Likewise, "mean daily minimum" (solid blue line) shows the average minimum temperature. Hot days and cold nights (dashed red and blue lines) show the average of the hottest day and coldest night of each month of the last 30 years. For vacation planning, you can expect the mean temperatures, and be prepared for hotter and colder days. Wind speeds are not displayed per default, but can be enabled at the bottom of the graph.

The precipitation chart is useful to plan for seasonal effects such as monsoon climate in India or wet season in Africa. Monthly precipitations above 150mm are mostly wet, below 30mm mostly dry. Note: Simulated precipitation amounts in tropical regions and complex terrain tend to be lower than local measurements.

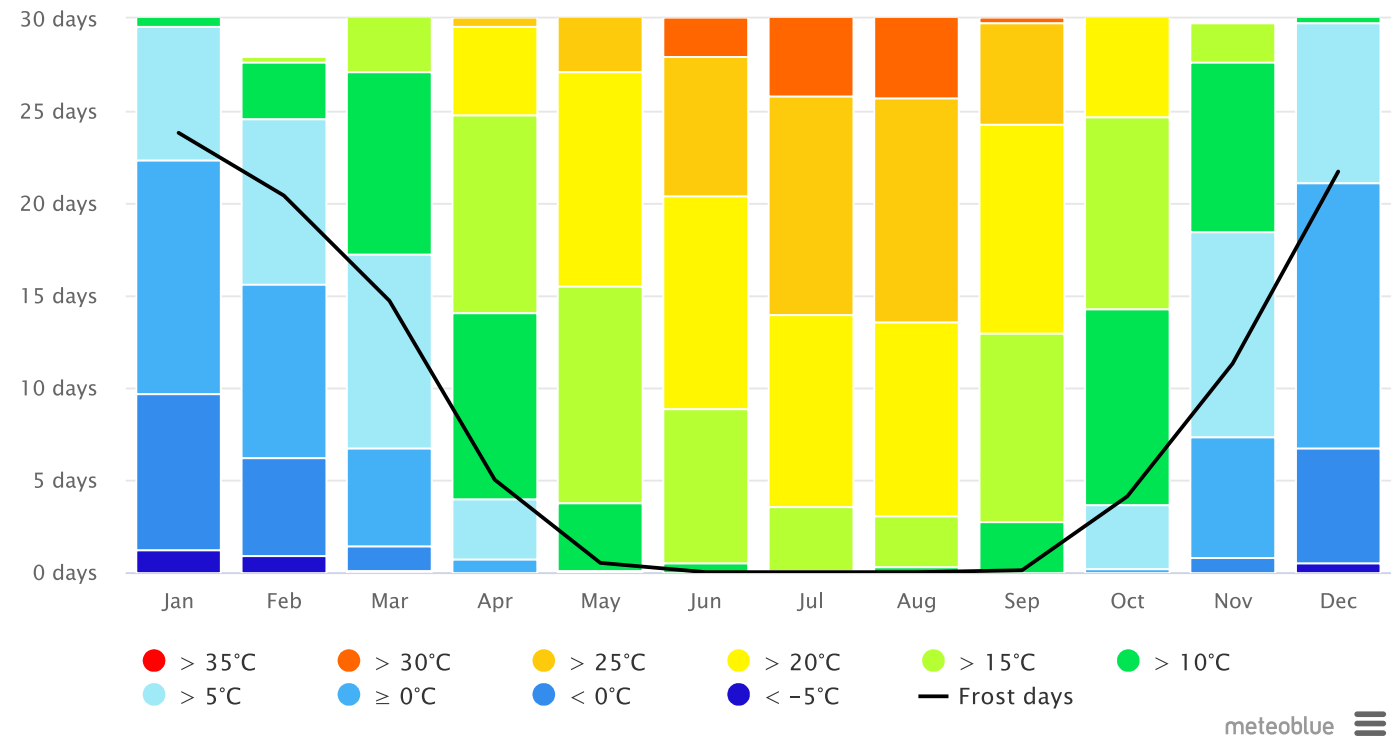
Cloudy, sunny, and precipitation days



The graph shows the monthly number of sunny, partly cloudy, overcast and precipitation days. Days with less than 20% cloud cover are considered as sunny, with 20-80% cloud cover as partly cloudy and with more than 80% as overcast. While Reykjavík on Iceland has mostly cloudy days, Sossusvlei in the Namib desert is one of the sunniest places on earth.

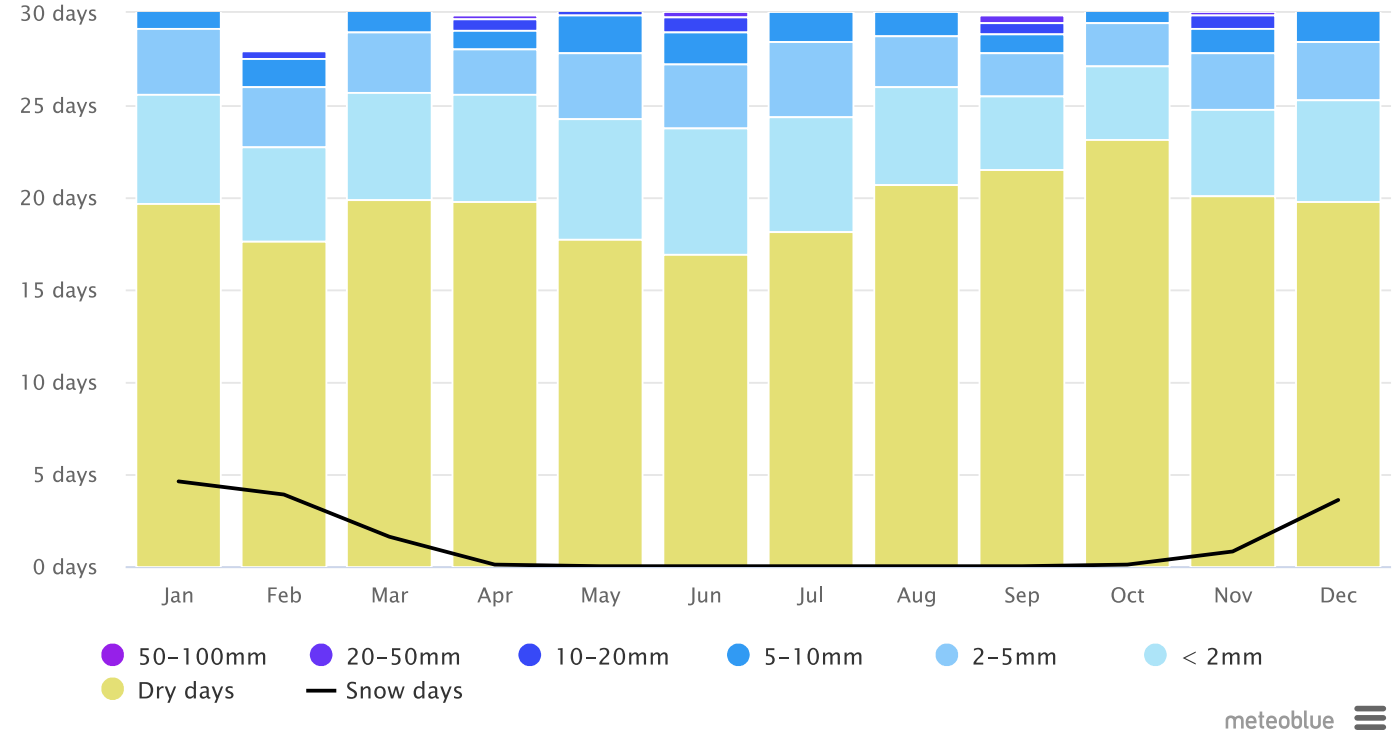
Note: In tropical climates like in Malaysia or Indonesia the number of precipitation days may be overestimated by a factor up to 2.

Maximum temperatures



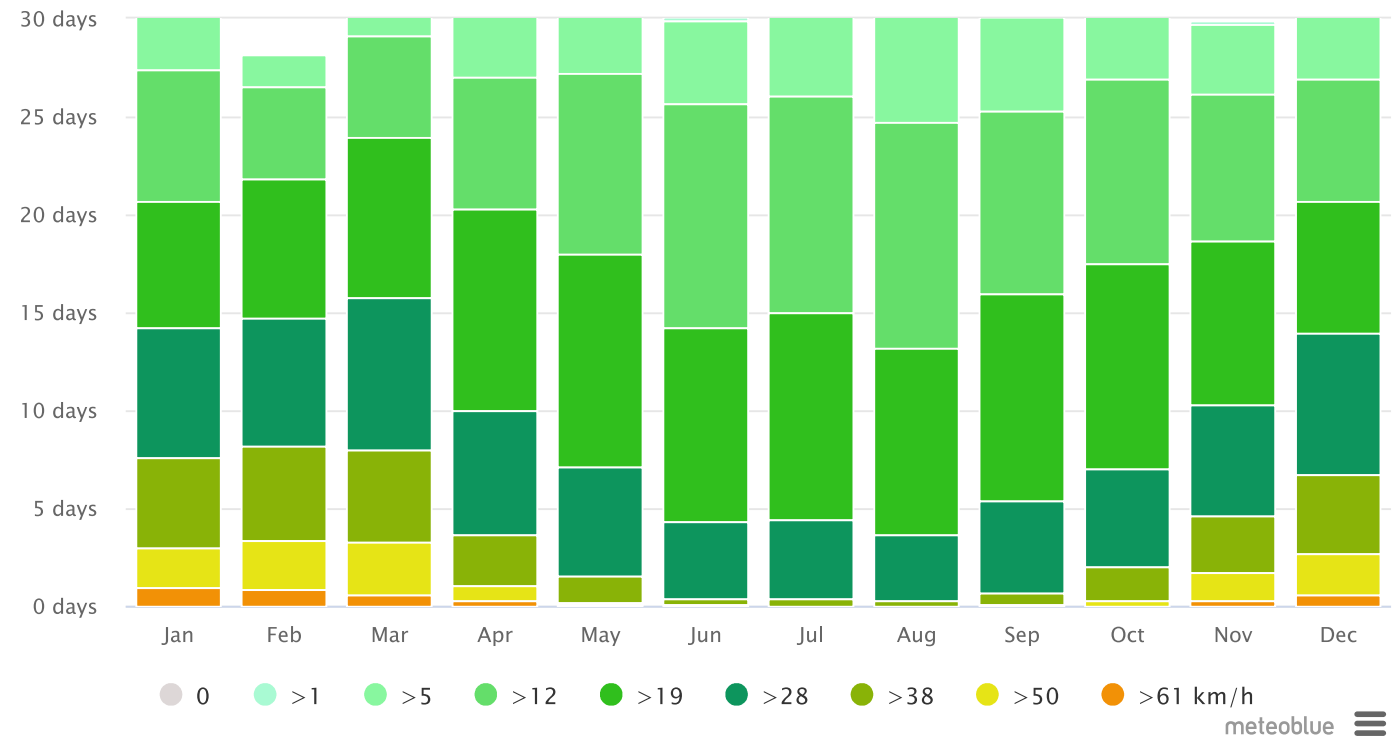
The maximum temperature diagram for Milovice displays how many days per month reach certain temperatures. Dubai, one of the hottest cities on earth, has almost none days below 40°C in July. You can also see the cold winters in Moscow with a few days that do not even reach -10°C as daily maximum.

Precipitation amounts



The precipitation diagram for Milovice shows on how many days per month, certain precipitation amounts are reached. In tropical and monsoon climates, the amounts may be underestimated.

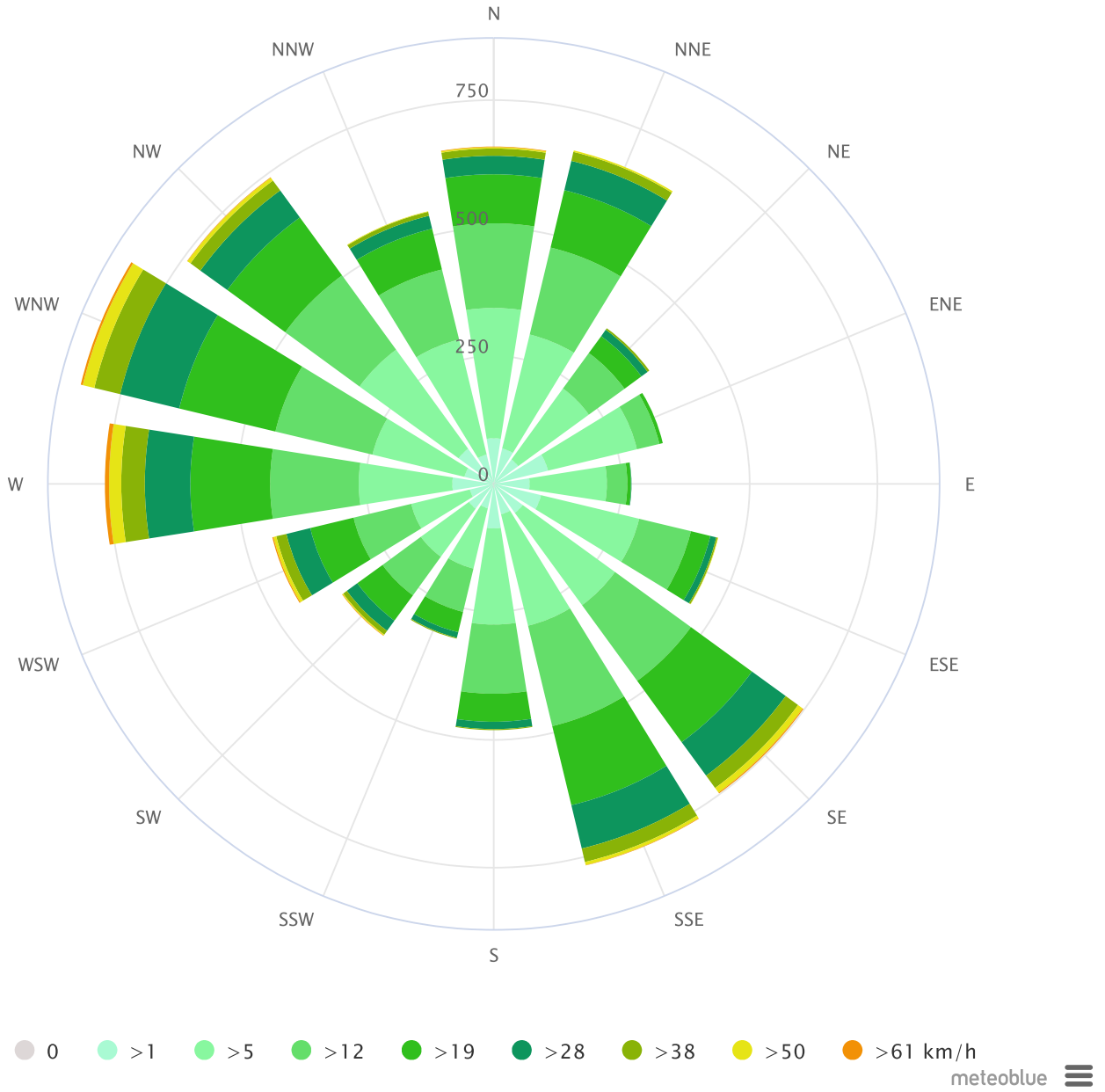
Wind speed



The diagram for Milovice shows the days per month, during which the wind reaches a certain speed. An interesting example is the Tibetan Plateau, where the monsoon creates steady strong winds from December to April, and calm winds from June to October.

Wind speed units can be changed in the preferences (top right).

Wind rose



The wind rose for Milovice shows how many hours per year the wind blows from the indicated direction. Example SW: Wind is blowing from South-West (SW) to North-East (NE). Cape Horn, the southernmost land point of South America, has a characteristic strong west-wind, which makes crossings from East to West very difficult especially for sailing boats.

General information

Since 2007, meteoblue has been archiving weather model data. In 2014 we started to calculate weather models with historical data from 1985 onwards and generated a continuous 30-year global history with hourly weather data. The climate diagrams are the first simulated climate data-set made public on the net. Our weather history covers any place on earth at any given time regardless of availability of weather stations.

The data is derived from our global NEMS weather model at approximately 30km resolution and cannot reproduce detail local weather effects, such as heat islands, cold air flows, thunderstorms or tornadoes. For locations and events which require very high precision (such as energy generation, insurance, etc.), we offer high resolution simulations with hourly data.

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GLOBAL SOLAR ATLAS
BY WORLD BANK GROUP

Milovice

48°51'48", 16°43'01"
Milovice, Southeast, Czechia
Time zone: UTC+01, Europe/Prague [CET] , Daylight saving time not considered

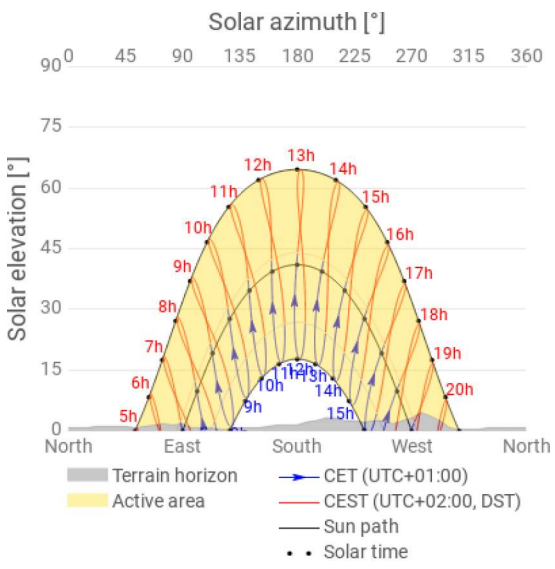
Report generated: 23 Mar 2021

SITE INFO

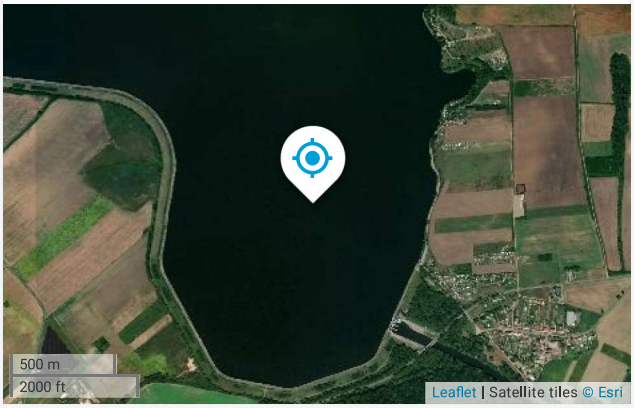
Map data

		Per year	
Direct normal irradiation	DNI	**1085**	kWh/m^2
Global horizontal irradiation	GHI	**1194**	kWh/m^2
Diffuse horizontal irradiation	DIF	**593**	kWh/m^2
Global tilted irradiation at optimum angle	GTI opta	**1392**	kWh/m^2
Optimum tilt of PV modules	OPTA	**36 / 180**	°
Air temperature	TEMP	**10.7**	°C
Terrain elevation	ELE	**164**	m

Horizon and sunpath



Map



PVOUT map

PVOUT: Long-term average of annual totals of PV power potential

kWh/kWp

600 800 1000 1200 1400 1600 1800 2000 2200 2400

PV ELECTRICITY AND SOLAR RADIATION

PV system configuration

Pv system: **Floating large scale**
Azimuth of PV panels: **Default** (180°)
Tilt of PV panels: **Default** (10°)
Installed capacity: **1000 kWp**

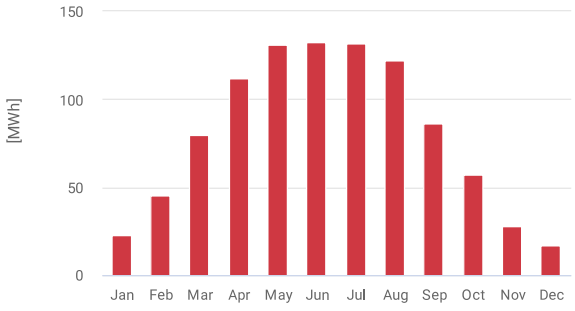
Annual averages

Total photovoltaic power output and Global tilted irradiation

964.833	1288
MWh per year	kWh/m^2 per year

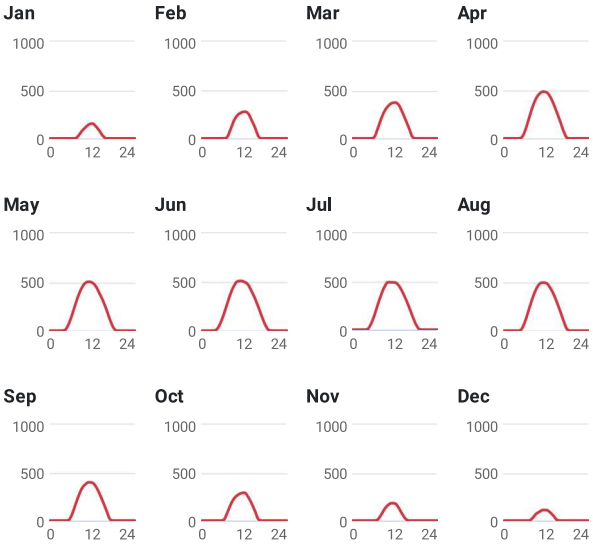
Monthly averages

Total photovoltaic power output



Average hourly profiles

Total photovoltaic power output [kWh]



UTC+01

Average hourly profiles

Total photovoltaic power output [kWh]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1												
1 - 2												
2 - 3												
3 - 4												
4 - 5					4	10	4					
5 - 6				13	51	64	49	20	2			
6 - 7			11	86	141	155	136	102	49	5		
7 - 8		13	95	201	253	263	248	215	147	73	10	0
8 - 9	28	90	199	316	360	371	354	326	249	162	58	23
9 - 10	77	182	283	405	441	451	440	417	332	227	120	66
10 - 11	114	237	334	456	489	498	486	474	375	263	162	90
11 - 12	144	263	364	478	500	502	485	490	396	283	181	108
12 - 13	153	273	371	473	490	491	483	484	390	289	177	107
13 - 14	123	256	348	432	451	465	452	441	349	246	134	85
14 - 15	77	188	275	358	380	399	392	377	277	179	70	50
15 - 16	25	109	190	265	305	322	315	290	192	96	18	8
16 - 17		19	101	168	212	232	228	194	101	12		
17 - 18			13	67	110	136	132	91	14			
18 - 19				4	28	52	49	12				
19 - 20					1	5	3					
20 - 21												
21 - 22												
22 - 23												
23 - 24												
Sum	740	1630	2583	3722	4216	4416	4256	3931	2872	1836	928	537

PV ELECTRICITY AND SOLAR RADIATION

Annual averages

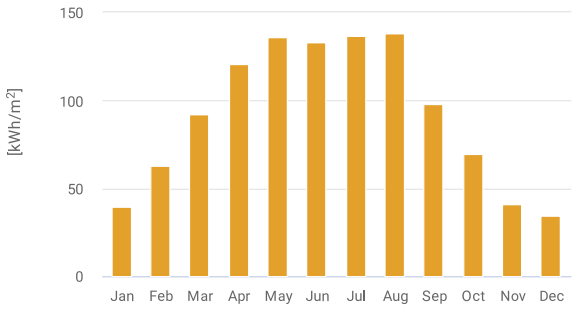
Direct normal irradiation

1102

kWh/m^2 per year

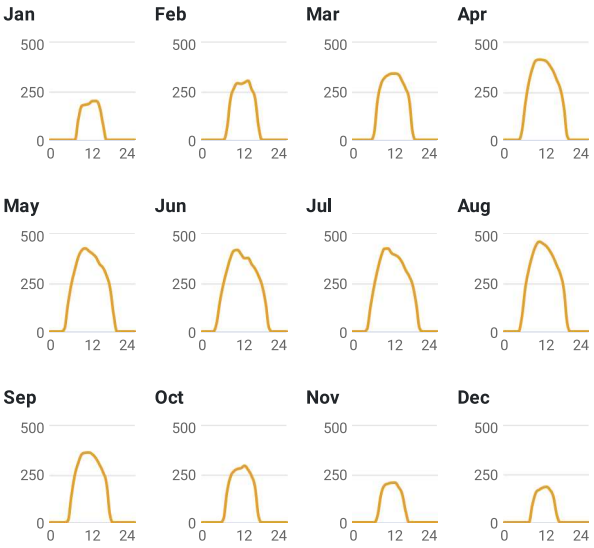
Monthly averages

Direct normal irradiation



Average hourly profiles

Direct normal irradiation [Wh/m^2]



UTC+01

Average hourly profiles

Direct normal irradiation [Wh/m^2]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1												
1 - 2												
2 - 3												
3 - 4												
4 - 5					13	37	11					
5 - 6				43	136	152	125	73	8			
6 - 7			32	187	242	242	228	224	136	16		
7 - 8		56	200	296	317	314	313	318	247	153	34	
8 - 9	106	207	284	369	382	376	383	389	311	234	144	89
9 - 10	173	264	317	410	416	413	423	439	354	264	190	151
10 - 11	179	289	331	415	425	417	424	459	361	275	200	167
11 - 12	184	286	338	413	411	396	401	450	363	280	204	178
12 - 13	198	293	339	406	398	375	391	436	353	292	205	182
13 - 14	198	302	333	383	380	376	379	412	332	272	182	167
14 - 15	169	259	300	353	345	345	353	379	299	239	146	131
15 - 16	79	212	262	309	326	321	314	337	261	180	56	37
16 - 17		68	205	262	286	284	283	293	201	30		
17 - 18			36	169	223	234	236	213	35			
18 - 19				16	88	146	140	38				
19 - 20						16	14					
20 - 21												
21 - 22												
22 - 23												
23 - 24												
Sum	1285	2235	2977	4030	4386	4444	4420	4459	3262	2235	1362	1101

GLOSSARY

Acronym	Full name	Unit	Type of use
DIF	Diffuse horizontal irradiation	kWh/m², MJ/m²	Average yearly, monthly or daily sum of diffuse horizontal irradiation (© 2019 Solargis)
DNI	Direct normal irradiation	kWh/m², MJ/m²	Average yearly, monthly or daily sum of direct normal irradiation (© 2019 Solargis)
ELE	Terrain elevation	m, ft	Elevation of terrain surface above/below sea level, processed and integrated from SRTM-3 data and related data products (© 2019 SRTM team)
GHI	Global horizontal irradiation	kWh/m², MJ/m²	Average annual, monthly or daily sum of global horizontal irradiation (© 2019 Solargis)
GTI	Global tilted irradiation	kWh/m², MJ/m²	Average annual, monthly or daily sum of global tilted irradiation (© 2019 Solargis)
GTI_opta	Global tilted irradiation at optimum angle	kWh/m², MJ/m²	Average annual, monthly or daily sum of global tilted irradiation for PV modules fix-mounted at optimum angle (© 2019 Solargis)
OPTA	Optimum tilt of PV modules	°	Optimum tilt of fix-mounted PV modules facing towards Equator set for maximizing GTI input (© 2019 Solargis)
PVOUT_total	Total photovoltaic power output	kWh, MWh, GWh	Yearly and monthly average values of photovoltaic electricity (AC) delivered by the total installed capacity of a PV system (© 2019 Solargis)
PVOUT_specific	Specific photovoltaic power output	kWh/kWp	Yearly and monthly average values of photovoltaic electricity (AC) delivered by a PV system and normalized to 1 kWp of installed capacity (© 2019 Solargis)
TEMP	Air temperature	°C, °F	Average yearly, monthly and daily air temperature at 2 m above ground. Calculated from outputs of ERA5 model (© 2019 NOAA and NASA)

ABOUT

This pdf report (the “Work”) is automatically generated from the Global Solar Atlas online app (https://globalsolaratlas.info/), prepared by Solargis under contract to The World Bank, based on a solar resource database that Solargis owns and maintains. It provides the estimated solar resource, air temperature data and potential solar power output for the selected location and input parameters of a photovoltaic (PV) power system.

Sources: Solar database and PV software © 2019 Solargis